Intel® Research mote

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Overview

- Intel mote project goals
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- Summary and outlook
- Intel mote prototype
Intel mote project goals

- Develop an enhanced universal mote building block
  - High platform integration level (core, radio, memory…)
  - Low power operation
  - Small physical size
  - Modular HW/SW design
  - System power management
  - Low cost and volume production potential

- Support and collaboration on sensor network research
  - Multi-hop networking
  - Power aware routing
Detailed research areas

- **Ultra low power operation**
  - Smart wireless communication
  - Battery lifetime of up to a year

- **System level integration**
  - CPU and radio component integration
  - RF direct to antenna output
  - System level partitioning and optimization
  - Integration of different technologies
    - Digital, analog, MEMS, memory...

- **Power and performance efficient HW reconfiguration**
  - Task specific acceleration
  - Flexibility with good power/performance trade-off
Project status and direction

We are here:
Intel mote prototype

1st generation Intel mote
Package level integration

2nd generation Intel mote
HW and SW improvements

3rd generation Intel mote
New integrated design

Future
Single chip with layered components

UCB mote

2002 2003 2004 2005

Sensor MEMS
Nonvolatile storage
RF MEMS
Digital/analog silicon
Battery
# Intel Research mote summary

**Enhanced building block for wireless sensor networks**

## Overview
- **CPU core**
  - Atmel
  - ARM
- **Wireless radio**
  - 900MHz
  - BT
  - Zigbee?
  - UWB?
- **Sensor interface**
  - Analog
  - Digital

## Current spec

## Applications
- Agriculture
- Process monitoring and control
- Firefighting and rescue
- Military
- Structure and earthquake monitoring

## Status
- Business model development studied
- Feedback from Berkeley Lab collected
- CPU/Radio component evaluation done
- Architecture specification completed
- Second prototype HW/SW created

## Participants
- Intel research labs
- Academic research
- Start-ups
1\textsuperscript{st} generation Intel mote goals

- Provide improved features
  - Reliability of radio links
  - Increased CPU performance
  - Security features
  - Modular design
  - Reduced cost

- Competitive battery life
  - Assumed duty cycle <1%
  - HW solutions: power down modes
  - SW solutions: smart networking protocols
Intel mote hardware

- Intel mote is a modular, stackable design
  - Power supply board (battery, AC, solar, …)
  - Main board (ARM core, SRAM, FLASH, BT radio)
  - Sensor board(s)
  - Other boards (alternate radio, debug, actuator, …)

- Backbone interconnect provides power, signaling
Intel mote and sensor net software

- Based on TinyOS
  - Port to ARM architecture
- Intel mote specific layer
  - BT support
  - Platform device drivers
- Network layer
  - Topology establishment
  - Single- and multi-hop routing
- Security features
  - Authentication
  - Encryption

TinyOS applications
TinyOS base
Network layer
Intel mote layer
Intel mote firmware (BT)
Intel mote hardware
Summary

The Intel mote project is now ~7 months old

Status
- Prototype HW developed
- TinyOS based SW stack near completion
- Start of pilot project investigations
  - Academic and commercial

Challenges for 2003
- Enable volume production in 1H 2003
- Promote Intel mote in research and industry
- Deliver easy to use Intel mote sensor network kit
- Start design of next generation Intel mote
Intel mote vs. Berkeley mote

- Original mote design by University of California at Berkeley

- Retained or extended features
  - TinyOS base
  - Modular design
  - Multi-hop networking

- New or changed features
  - ARM based CPU core
  - BT radio
Why Bluetooth?

 Availability of SOC integrated devices
- Single chip BT/controller/memory
- Low cost, availability from many sources
- On technology curve 0.18u -> 0.13u this year

 Radio features
- Link level reliability and security provisions
- Nominally higher power (~3-5x single channel 900MHz radios)
  - 7-10x higher bandwidth
  - Spread spectrum operation increases link reliability
  - Precise synchronization within piconets
- Looking forward to measuring effective power consumption
Intel mote technical details

- **ARM core**
  - 12MHZ
  - 64kB SRAM
  - 512kB FLASH

- **BT radio**
  - Up to +4dbm transmit
  - -80dbm receive
  - >30m range

- **Battery life (projected) at 1% duty cycle**
  - >1 month with coin cells
  - >6 months with AA cells

- **I²C backbone interconnect**
  - 100kb/s transfer rate (up to 400kb/s in future revisions)

- **Debug connector**
  - UART, USB slave, JTAG